

A deep space photograph showing a vast field of stars against a dark background. A particularly bright star in the lower-left corner exhibits a prominent diffraction pattern with multiple rays of light. Other stars of varying brightness and colors (white, blue, yellow) are scattered across the frame.

What Cosmology/Astrophysics and Neutrino Physics Can Teach Each Other

Working Group Leaders:
Steve Barwick and John Beacom

Perspective

"If [there are no new forces] ---- one can conclude that there is no practically possible way of observing the neutrino." Bethe and Peierls, Nature (1934)

Cosmological

- Big-bang nucleosynthesis consistency
- Neutrino hot dark matter models ruled out

Astrophysical

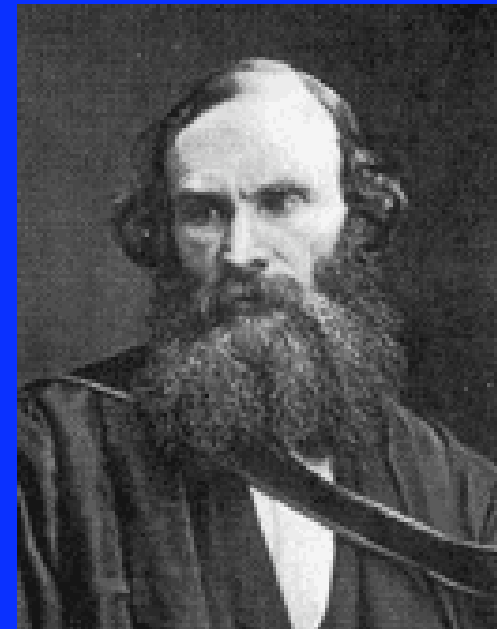
- Neutrinos from SN 1987A observed
- The solution of the solar neutrino problem

State of the Field

*“There is nothing new to be discovered in physics now,
All that remains is more and more precise measurement.”*

-- Kelvin, c. 1900

- We now understand neutrinos
(Yeah, right)
- We now understand cosmology
(Yeah, right)
- We now understand astrophysical sources
(Yeah, right)



Major Topics

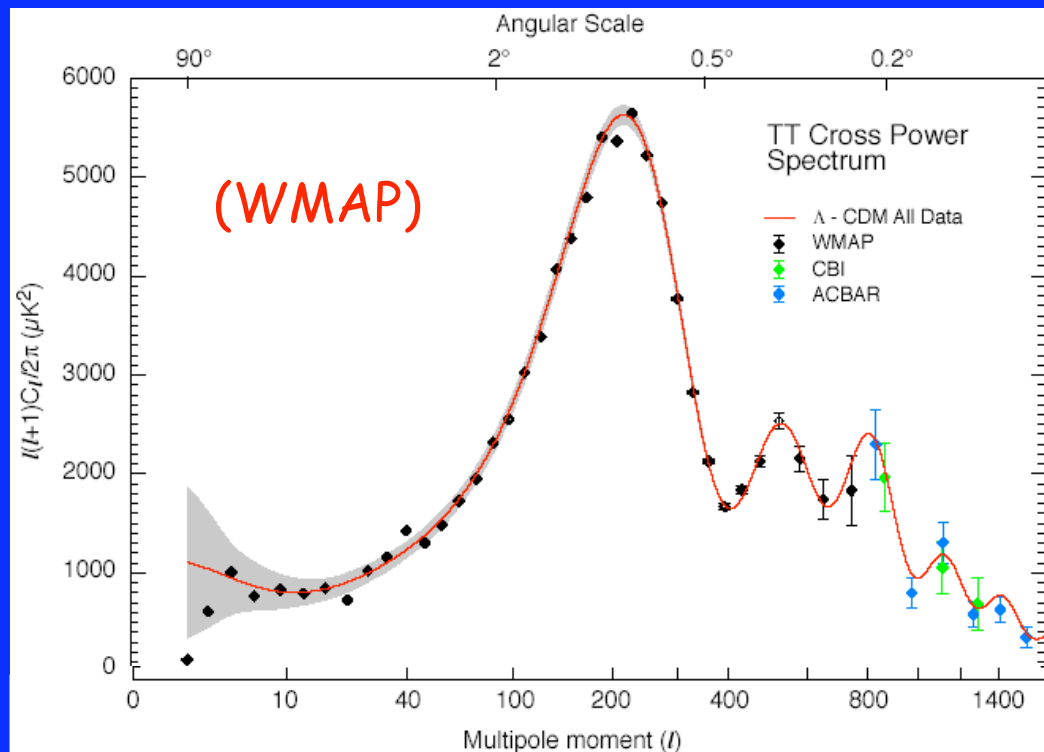
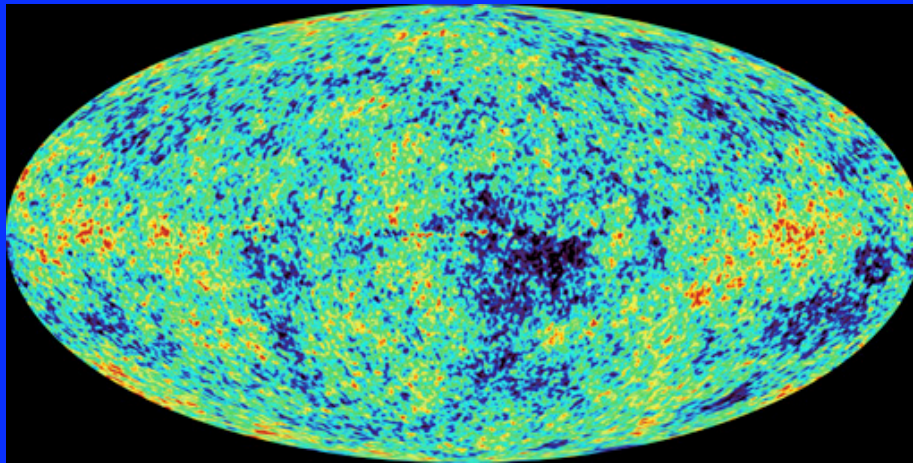
- Leptogenesis
- BBN
- Dark energy
- Dark matter
- WIMP detection
- UHE neutrinos
- SN neutrinos



- Number of flavors
- Sterile neutrinos
- Dirac vs. Majorana
- Mass scale
- Mixing parameters
- Cross sections
- Exotic properties

Neutrinos are a key to
New physics in the Universe
New physics beyond the Standard Model

Cosmological Parameters



$$\Omega_{\text{total}} = 1.02 \pm 0.02$$

$$\Omega_{\text{matter}} h^2 = 0.14 \pm 0.01$$

$$\Omega_{\text{baryon}} h^2 = 0.022 \pm 0.001$$

$$\Omega_{\text{neutrino}} h^2 < 0.01$$

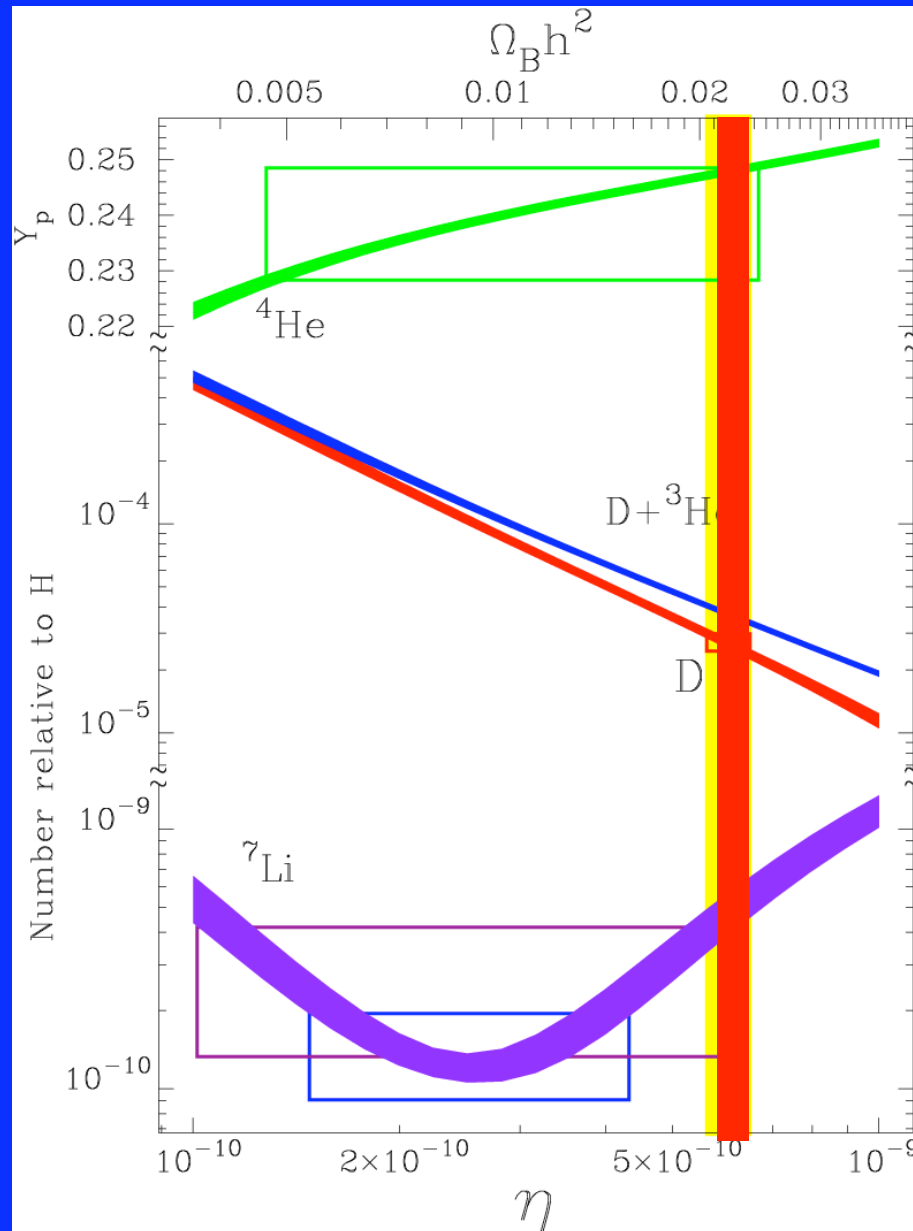
$$h = 0.71 \pm 0.04$$

etc.

$$\Omega_{\Lambda} = 0.7$$

$$m_{\nu} < 0.23 \text{ eV}$$

Neutrino Number Densities



$$\rho_\nu = \sum m_\nu n_\nu$$

$N_\nu < 4$ (99%CL) BBN

Abazajian, Astropart. 19, 303 (2003)

$1.5 \leq N_\nu \leq 7.2$ WMAP++

Crotty, Lesgourgues, and Pastor,
PRD 67, 123005 (2003)

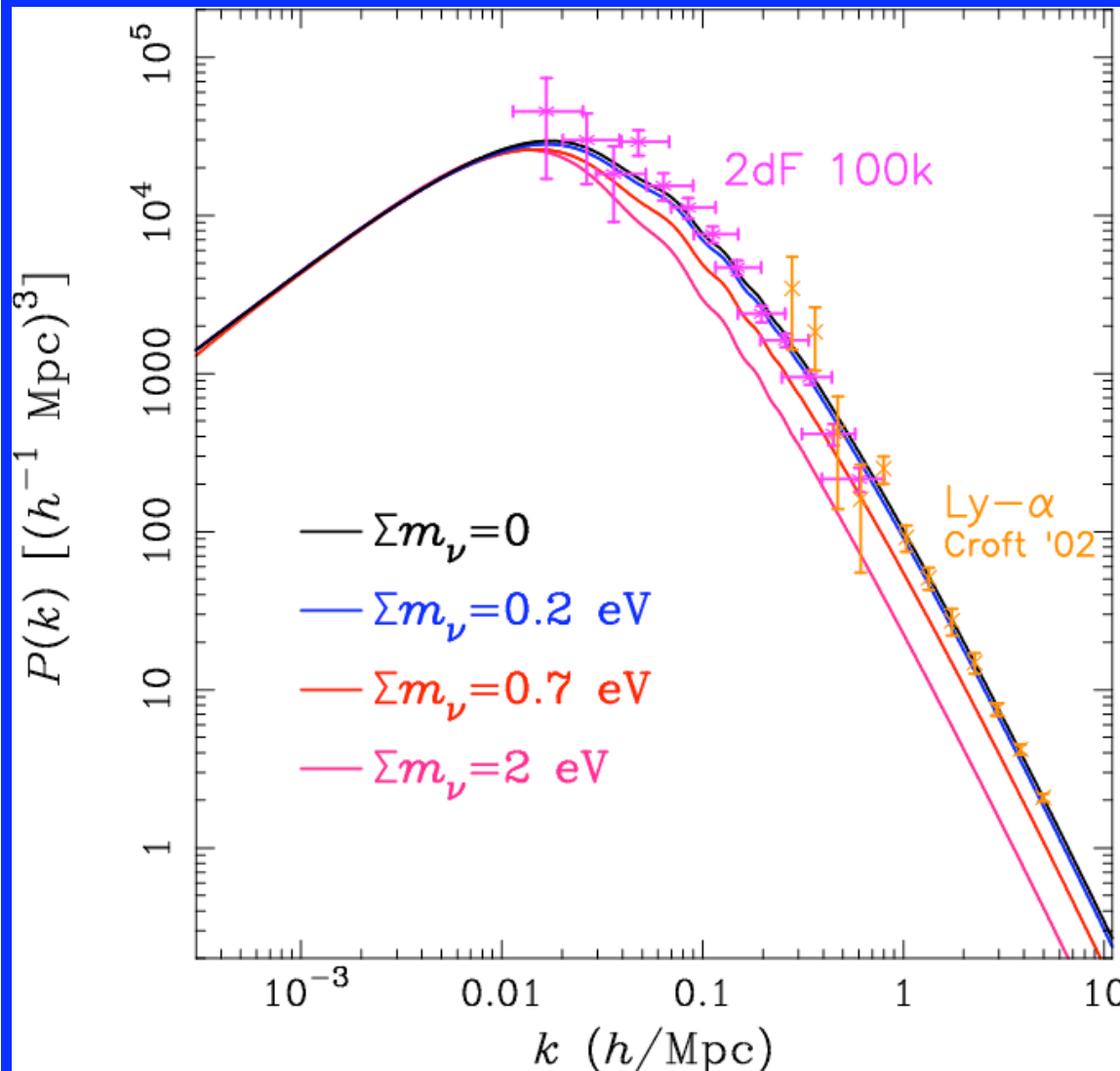
$$n_\nu \simeq n_{\bar{\nu}}$$

Dolgov et al., NPB 632, 363 (2002);

Wong, PRD 66, 025015 (2002);

Abazajian, Beacom, and Bell,
PRD 66, 013008 (2002)

Neutrino Dark Matter



(graphic from Kev Abazajian)

$$\rho_{\text{matter}} = \rho_{\text{CDM}} + \rho_{\text{baryons}} + \rho_{\text{neutrinos}}$$

$$\rho_\nu = m_\nu n_\nu$$

Future discovery range:
Abazajian & Dodelson,
PRL 91, 041301 (2003)

Kaplinghat, Knox & Song,
astro-ph/0303344

Funding Issues

Neutrino Cosmology

- Data are “cruelty free” for neutrinos
- Experiments are independently (?) justified

Neutrino Astrophysics

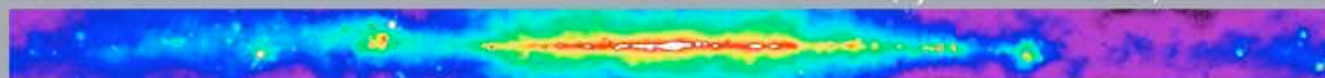
- Requires detection of individual neutrinos
- Is it really “astronomy”? This adds to confusion about nuclear vs. particle purview

Key role of cross-disciplinary efforts in theory

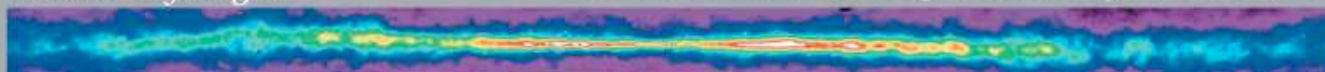
Photon Windows

Multiwavelength Milky Way

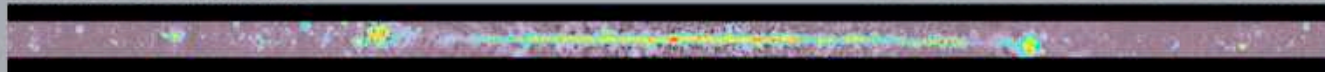
Radio Continuum 408 MHz Bonn, Jodrell Banks, & Parkes



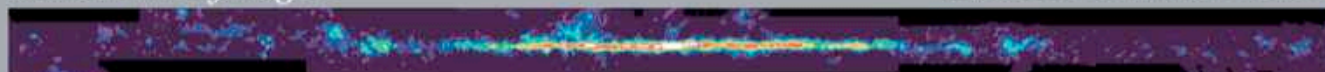
Atomic Hydrogen 21 cm Leiden-Dwingeloo, Maryland-Parkes



Radio Continuum 2.4-2.7 GHz Bonn & Parkes



Molecular Hydrogen 115 GHz Columbia-GISS



Infrared 12, 60, 100 μm IRAS



Near Infrared 1.25, 2.2, 3.5 μm COBE/DIRBE



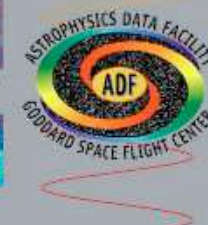
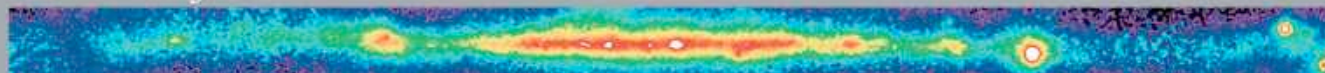
Optical Laustsen et al. Photomosaic



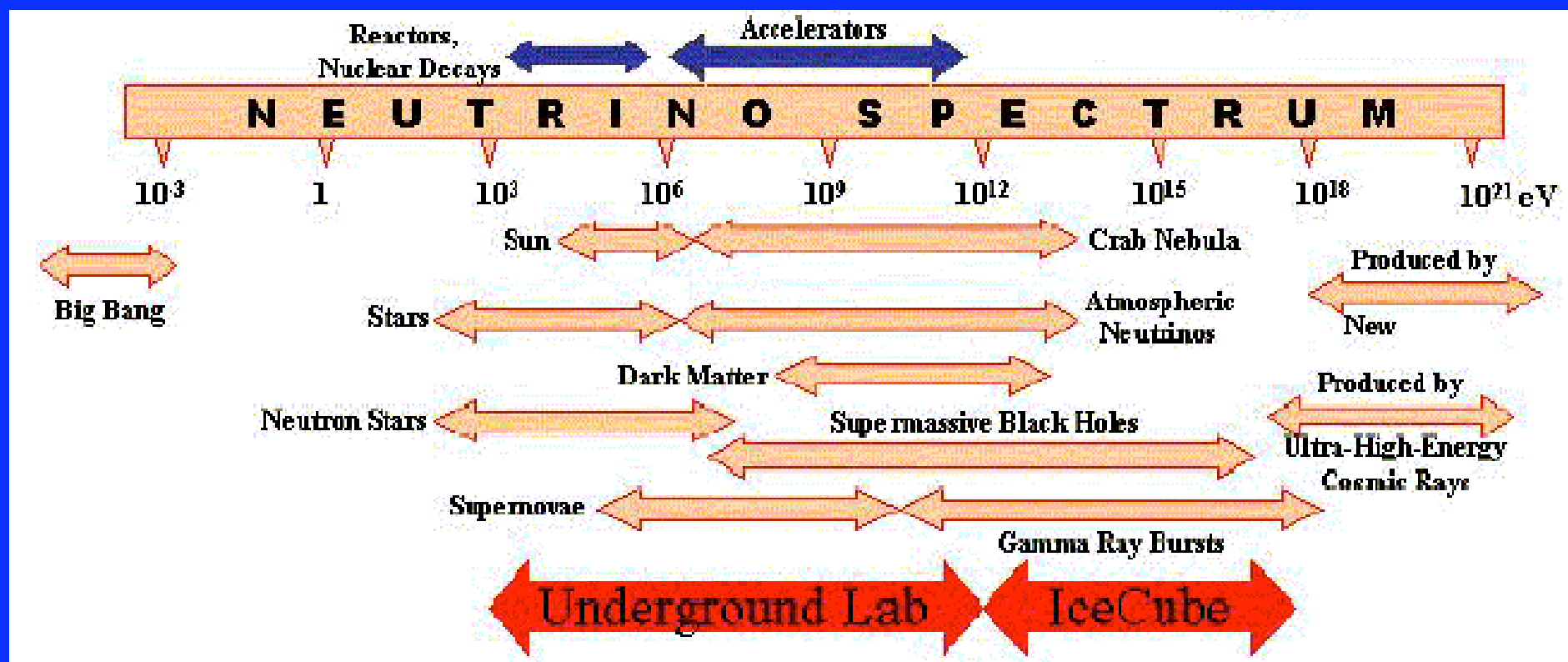
X-Ray 0.25, 0.75, 1.5 keV ROSAT/PSPC



Gamma Ray >100 MeV CGRO/EGRET

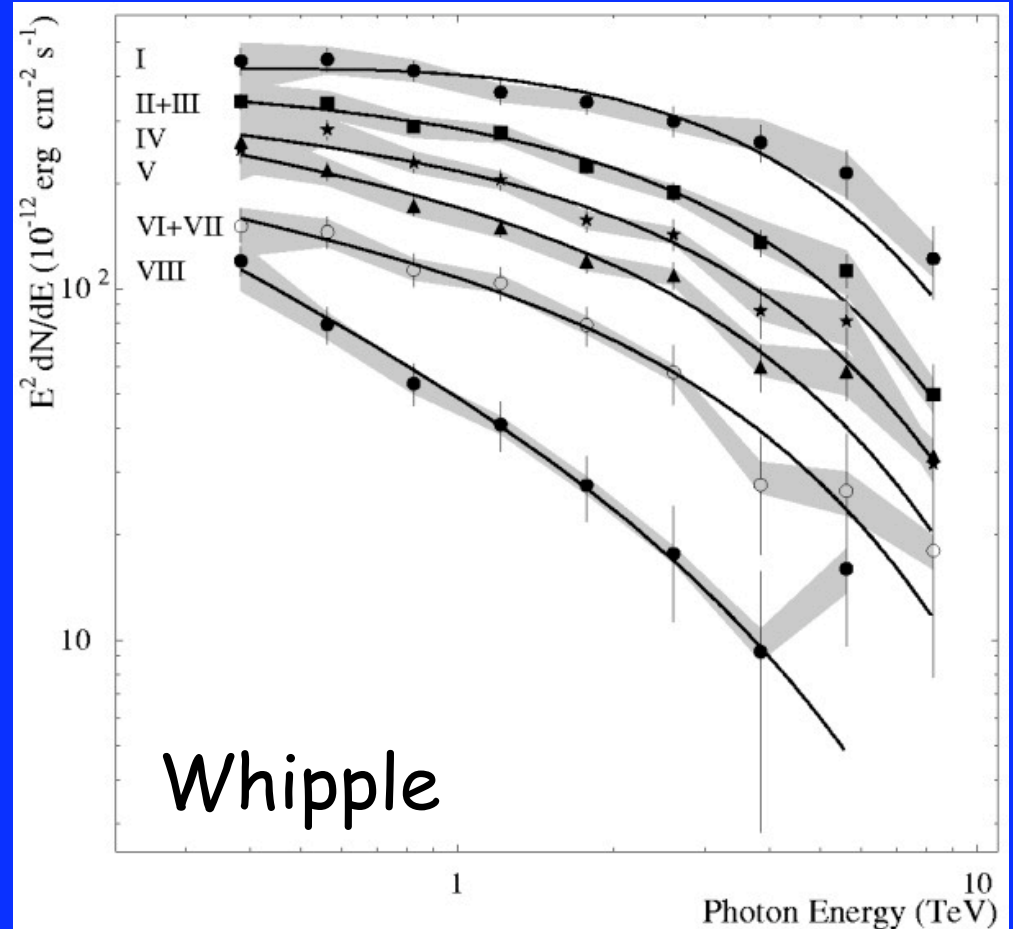
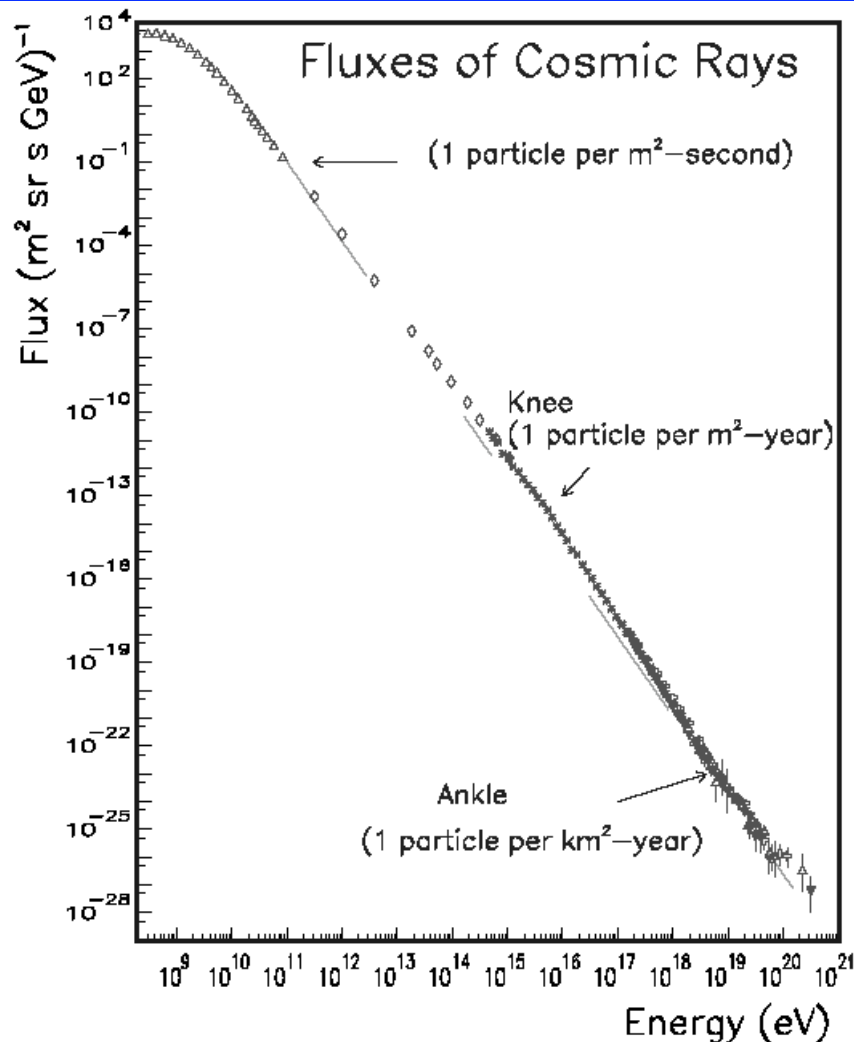


Neutrino Windows



Neutrino Facilities Assessment Committee, NAS (2002)

High Energy Messengers

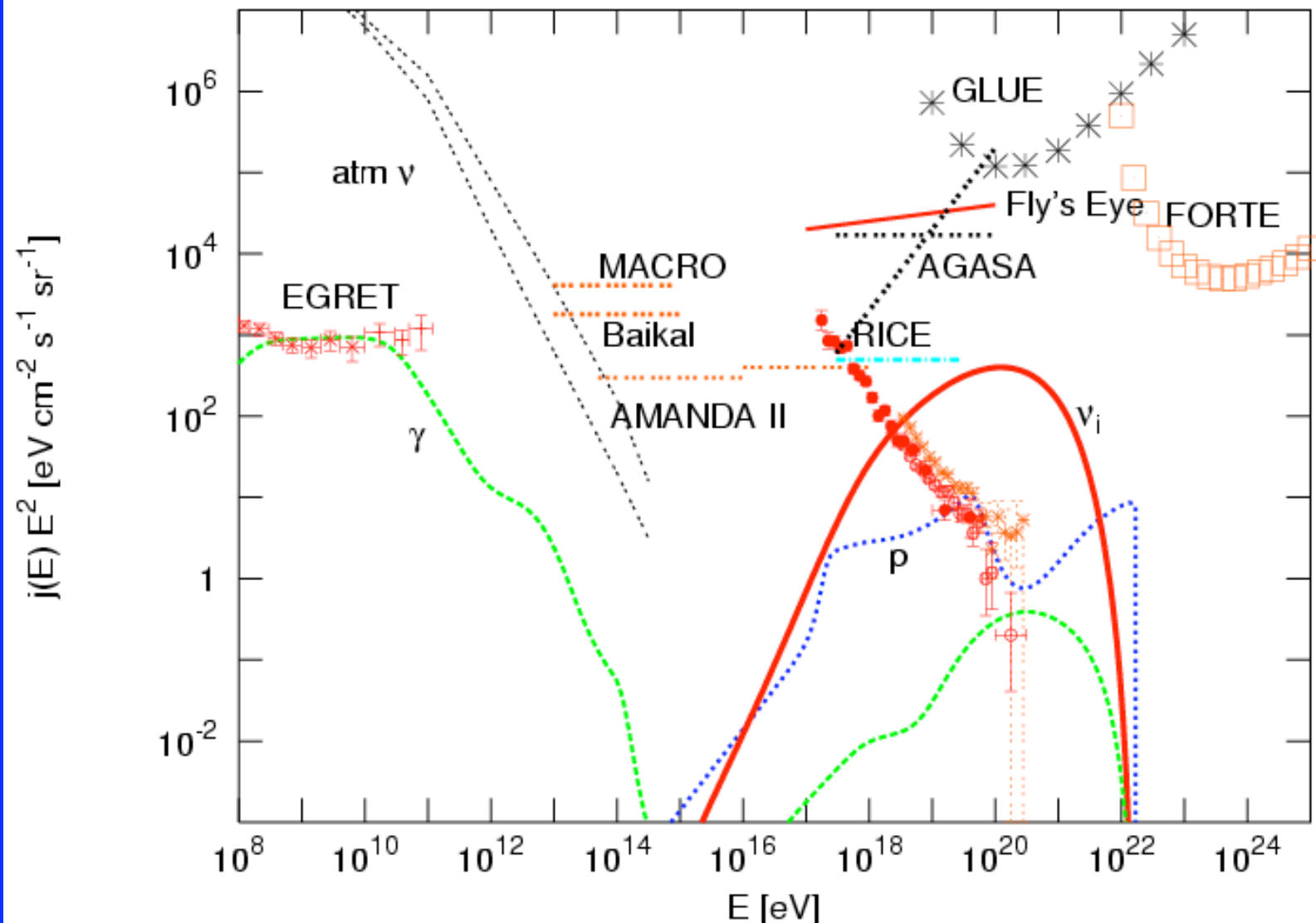


F. Krennrich et al., ApJ 575, L9 (2002)

Protons (diffuse)

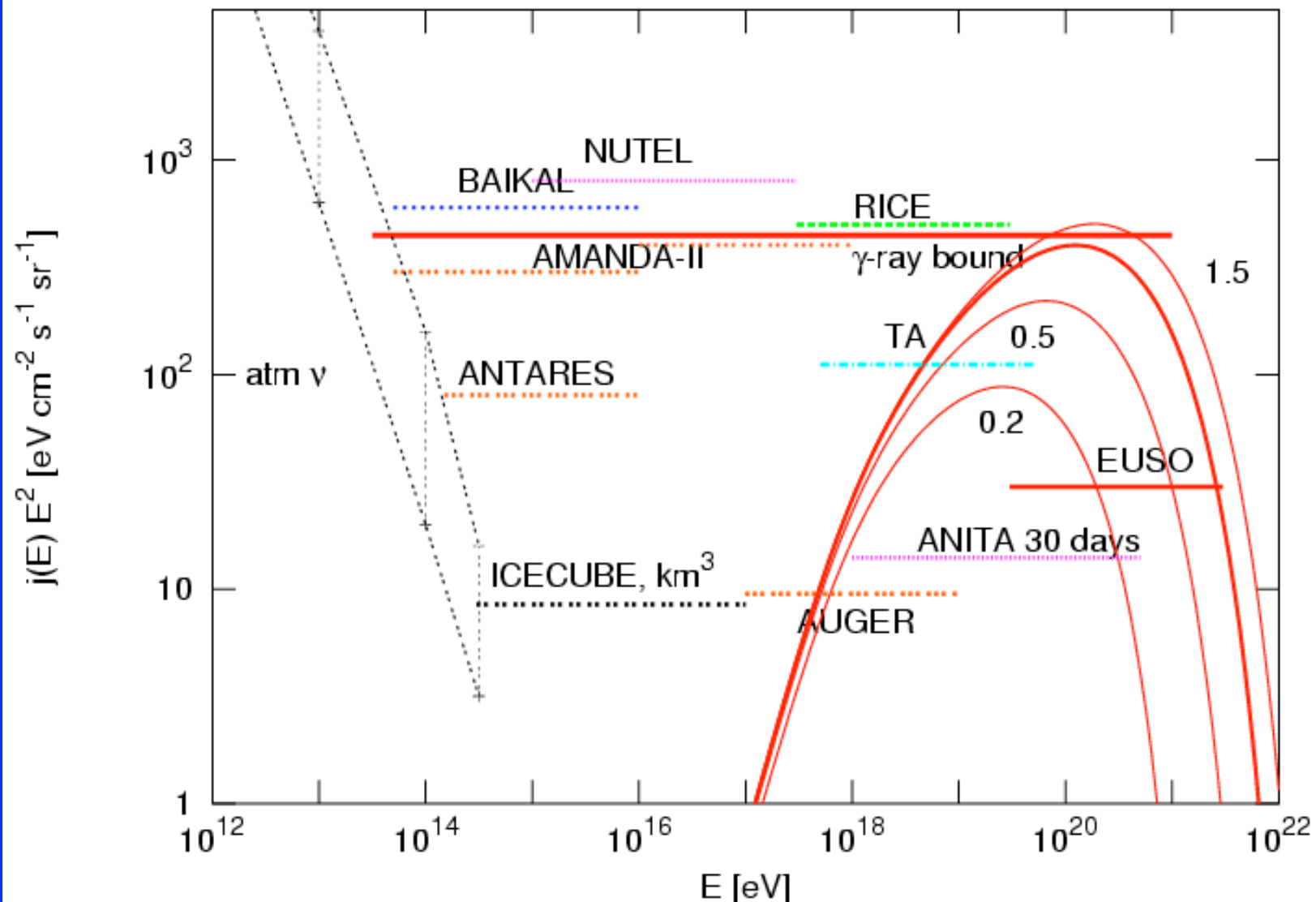
Photons (Markarian 421)

Existing Neutrino Limits



Semikoz, Sigl, hep-ph/0309328

Future Neutrino Sensitivity



Semikoz, Sigl, hep-ph/0309328

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Working Group Plans

- Specific details to be determined
- Will provide updates through a web page
- Your participation and comments are welcomed
- Contact information:

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